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Evaluation of Varieties and Cultural Practices of Okra (Abelmoschus Esculentus) for Production in Massachusetts

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EVALUATION OF VARIETIES AND CULTURAL PRACTICES OF OKRA (ABELMOSCHUS ESCULENTUS) FOR PRODUCTION IN MASSACHUSETTS

A Thesis Presented

by

RENATO FARIA MATEUS

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Robert Wick, Member

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Stephen Rich, Department Head
Plant, Soil & Insect Sciences

DEDICATION

To my wife Celina.

Your love has inspired and encouraged me to pursue this achievement.

ACNOWLEDGMENTS

First, I would like to thank God and Nossa Senhora da Guia, for giving me the strength and determination to finish this thesis.

Thanks to my advisor, Dr. Frank Mangan, for allowing me to join his team. Thanks also to Dr. Wesley Autio and Dr. Robert Wick, for serving on my committee with patience and guide me to the right path with wise comments and advises along this road.

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I also want to thank all of my Amherst friends for the memories that I will keep for the rest of my life.

A very special thanks to my father, who always trusted me and taught me how to be a man when you are not treated as one and never lose the desire to go in pursuit of happiness.

I thank my wife Celina, who stood beside me and was the mainstay of this work.

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CHAPTER 1

INTRODUCTION

Okra (*Abelmoschus esculentus*), called "quiabo" in Portuguese belongs to the Malvaceae for which cotton is also a member. Okra is a warm-season crop that is considered to have originated from India (Rao, 1985), and it is a traditional vegetable crop commercially cultivated in West Africa, India, Southeast Asia, the southern United States, Brazil, Turkey and northern Australia (Duzyaman, 1997).

The fruits are a green capsule containing numerous white seeds when immature (Jesus et al., 2008) and the flowers and upright plants give okra an ornamental value (Duzyaman, 1997) (Figure 1). The okra fruit can be classified based on the shape, angular or circular (Mota et al., 2005).

Figure 1.1. Flower of okra (*Abelmoschus esculentus*).

Fresh okra is a popular ingredient of soups and stews where a highly viscous consistency is desired (Baxter, 1990). Okra has a high nutritional value and grows very quickly with high temperatures, which lends its production to more tropical parts of the world (Costa et al., 1981).

Okra seeds are a source of oil, protein and are also used as a coffee substitute, while ground-up okra seeds have been used as a substitute for aluminum salts in water purification (Camciuc et al, 1998). The nutritional value of 100 g of edible portion of okra contains 1.9 g of protein, 0.2 g fat, 6.4 g carbohydrate, 0.7 g minerals and 1.2 g fiber (Tiwari et al, 1998).

Okra production is affected by climatic factors and cultural practices, including planting density. When the okra variety Sabz Pari was planted at spacings of 60 x 15, 60 x 30 or 60 x 45 cm, Amjad (2001) found that the lowest planting density (3.7 plants.m^{-2}) resulted in the maximum number of 14.43 mature pods per plant and the highest planting density (11.1 plants.m^{-2}) had the lowest number of 11.3 pods per plant of okra. This was probably because in the lowest planting density, plants receive more nutrients and lateral growth takes place resulting in increased number of pods per plant.

Verticillium wilt causes severe reductions in yield in a variety of important crops worldwide (Lazarovits et al., 2000). Verticillium wilt of okra was first reported by Wollenweber in 1913 from South Carolina (Strobel, 1961). The fungus is common in many soils and is capable of surviving in soil without the host plant (Strunnikova et al., 2000). The pathogen persists in the soil as microsclerotia, the bodies being formed in the decaying tissue of host crops from which they eventually are released into the soil (Locke and Buck, 2000).

In Brazil, the most commonly grown cultivars are Colhe Bem and Santa Cruz 47 with both varieties producing round pods (Purquerio et al., 2010). Many parts of Brazil have a favorable climate for the production of okra; it is most popular in the Northeastern and Southeastern parts of the country (Mota et al., 2000). In 2009, about seven tons of okra were sold in at the warehouse CEAGESP (Companhia de Entrepostos e Armazéns Gerais de São Paulo), in the state of Sao Paulo and the period of greater supply corresponded to the months January to April (AGRIANUAL, 2010).

In the United States, okra is most popular in the southern part of the country, but the development of cultivars with early maturity allows cultivation in the north (Hill, 2001). The leading okra-producing states are Texas, Florida, Georgia and California (Izekor & Katayama, 2001). Currently, the most popular okra varieties grown in Florida are Annie Oakley, Cajun Delight, Clemson Spineless, North and South, and Spike (Simonne et al., 2010). Okra can be grown in Massachusetts using the same production practices used in Florida (Hochmuth, 1999).

Okra is an important cash crop in the Homestead area of Florida, with up to 1,500 hectares planted per year (Olczyk et al., 2005). Based on the study conducted with okra at densities of 2.4 to 14.0 plants.m^{-2}, Whitehead and Singh (2000) reported linear and quadratic increases in yield as plant density increased during two seasons of trials. Albregts and Howard (1974) planted okra in Central Florida comparing 16, 32 and 64 plants.m^{-2} and found an increasing yield with increasing plant density and, increasing plant density resulted in decreasing pod size.

When grown okra in Florida on mulch with drip irrigation, Simonne et al. (2009) recommends to broadcast all P_2O_5, micronutrients, and up to 20 to 25% of N and K_2O in the bed. According to the New England Vegetable Management Guide (New England Vegetable Management Guide, 2008-2009) recommendations for okra is to apply lime according to soil test to maintain a soil pH at 6.5 to 7.0, and in soils with high phosphorus levels and very high potassium levels, 145kg of N ha^{-1} and 56kg of P_2O_5 ha^{-1} should be applied to the soil.

According to Duzyaman (1997), a yield of 7 to 12 ton.ha^{-1} of immature fruits of okra is considered excellent yield. A study carried out by Tiwari (1998) in India, to evaluate drip irrigation in combination with black plastic mulch found a yield of 14.57 ton.ha^{-1} of green fruit of okra using a density of 55000 plants per hectare.

The foreign-born population in Massachusetts has been increasing in recent years (Fair, 2011). This large and growing population has a strong preference for their traditional cuisine, and okra represents a market with strong potential for local producers (Mendonca et al., 2007).

A Brazilian dish called “Frango com Quiabo” (chicken with okra) is especially famous in Minas Gerais, the state of origin of a very high percentage of Brazilians living in Massachusetts. According to the Brazilian Ministry of International Relations (Brasileiros no Mundo, 2009), there are about 350,000 Brazilians living in New England. Research at the University of Massachusetts has been implemented on two crops popular among Brazilians, jiló (*Solanum gilo*) and abóbora japonesa (*Cucurbita maxima x Cucurbita moschata*), which have allowed the successful adoption of these crops by commercial farmers (Mendonca, et al., 2007).

United States imports a large volume of okra. According to the FAO 2011, United States imported 38,223 tons of okra in 2008. Due to the growing ethnic population in the U.S. that use okra in their cuisine, okra presents an opportunity for Massachusetts producers to capitalize on the demand. In 2009, there were 1,276 hectares of okra in production in the United States with a yield of 9,835 tons (FAO, 2011).

CHAPTER 2

EVALUATION VARIETIES OF OKRA (*ABELMOSCHUS ESCULENTUS*) FOR PRODUCTION IN MASSACHUSETTS

2.1 Introduction

Okra (*Abelmoschus esculentus*), called “quiabo” in Portuguese belongs to the Malvaceae for which cotton is also a member. The fruits are a green capsule containing numerous white seeds when immature (Jesus et al., 2008) and the flowers and upright plants give okra an ornamental value (Duzyaman, 1997). The okra fruit can be classified based on the shape, angular or circular (Mota et al., 2005).

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This crop is widely grown in southern parts of the United States as an annual vegetable crop. The leading okra producing states are Texas, Florida, Georgia and California (Izekor & Katayama, 2001). Currently, the most popular okra varieties grown in Florida are Annie Oakley, Cajun Delight, Clemson Spineless North and South, and Spike (Simonne et al., 2010). Okra can be grown in Massachusetts using the same production practices used in Florida (Hochmuth, 1999).

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The purpose of this work was to evaluate different varieties of okra for their adaption to the New England climate.

2.2 Material and Methods

The experiment was carried out in 2009 and 2010 at the UMass Research Farm in South Deerfield, MA. The soil at the UMass Research Farm is an Occum fine sandy loam (coarse-loamy, mixed, mesic Fluventic Dystrudept). The trial was designed as a randomized complete block with five replications. In 2009, there were seven varieties of okra: Annie Oakley, Baby Bubba, Cajun Delight, Chifre de Veado, Clemson Spineless, North & South and Santa Cruz 47. In 2010, the additional variety Millionaire was included in the trial.

The measurements for the plots were 1.52 m X 1.83 m with twelve plants spaced 30.0 cm apart arranged in a double row with 30 cm between rows, on a raised bed with black plastic mulch and drip irrigation. The plastic was laid 1.83 m on center.

Seedlings were produced in round plastic flats with 72 cells (91 $cm^3.cells^{-1}$). Pro-Mix Bx (Premier Horticulture) was used as growing medium. Two seeds were placed in each cell and thinned to one plants per cell two weeks after seeding. The flats were placed in a mist house (24 ^oC day and night temperatures) until germination, and then transferred to a greenhouse (21 ^oC day and 18 ^oC night temperatures) with the regime of fertilizer (Technigro 17-5-24, 200 ppm Nitrogen) applied as a constant feed. Plants were transplanted to the field 27 days after seeding in the greenhouse in 2009 and 30 days in 2010 (Table 2.1). Plants were transplanted into 8 cm raised beds, spaced 1.83 m on center, covered with black plastic with drip irrigation to apply water and fertilizer when needed.

Table 2.1. Dates for selected actions for okra grown on the Variety trial. South Deerfield, UMass-Amherst, 2009 and 2010.

Action	2009	2010
Seeded in the greenhouse	May 20	May 4
Thinned in the flats	June 4	May 21
Transplanted into the field	June 16	June 3
First Harvest	July 23	July 5
Last Harvest	September 7	September 29

Water was applied via drip irrigation as needed based on soil moisture readings from tensiometers (Irrometer Co Riverside CA) placed at 15, 30, and 45 cm depths in the soil in between two plants and the drip tape, as recommended by the Irrometer Company, in one randomly selected plot.

Fertilizer was applied through the drip system in the form of a complete fertilizer (20% N - 20% P_2O_5 - 20% K_2O) and calcium nitrate (15.5% N - 0% P_2O_5 - 0% K_2O)

according to soil tests taken in the early spring and based on the recommendations from the New England Vegetable Management Guide 2008-2009. The total amount of fertilizer applied through the drip system was (kg.ha^{-1}): 80.27 N, 14.2 P_2O_5, 14.2 K_2O for 2009 and 105.36 N, 62.55 P_2O_5 and 60.10 K_2O in 2010. Weeds between plastic beds and in the holes were removed by hand. Cutworms (*Agrotis sagetum*) were found in the 2009 experiment and one application was made with Asana XL (active ingredient: esfenvalerate) at rate of 630 g.ha^{-1} on June 16. Japanese beetle (*Popillia japonica*) and aphids (*Lipaphis erysimi*) were controlled in 2010 by one application of Admire 2F (1.46 liters.ha^{-1}; a.i. imidacloprid) applied through the drip system on June 30.

Harvest began 37 days after planting in 2009 and 32 days after planting in 2010. The immature pods of all the varieties used in this experiment were harvested when the fruits reached 70 mm in length (the size desired by the market in the USA) and specifically for Chifre de Veado and Santa Cruz 47; another plot was set and the immature pods were harvested when reached 100 mm (the size desired by the market in Brazil).

Okra pods appeared about five days after blooming, and grow very quickly depending on the temperature. Since okra pod tenderness, decreases as the pod size increases, harvest was done three times a week. Five plants in the center of the plot were randomly selected for all harvests. The pods were counted and weighted. A sub-sample of five fruits per plot was randomly chosen to measure fruit length and fruit diameter using a digital caliper. Yield was expressed by number of pods and total weight.

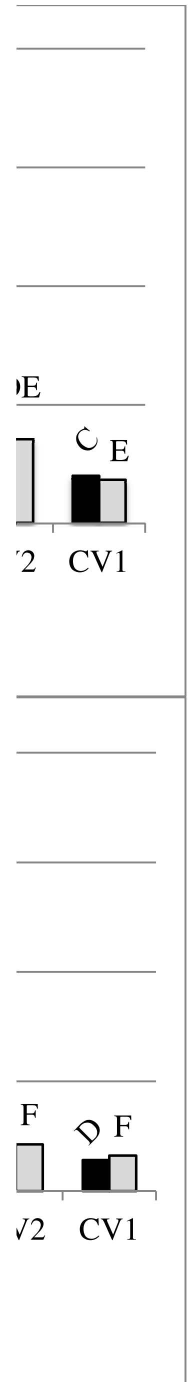
Analyses of variance were performed by SAS, and means were compared using Duncan's new multiple range test (P = 0.05).

2.3 Results and Discussion

Significant differences were observed among varieties for yield ($ton.ha^{-1}$) and pod numbers ($pod.ha^{-1}$) for all the varieties in this trial for in 2009 and 2010 (Figure 2.1).

In 2010, Santa Cruz 47 harvested based on Brazilian market size (SC2) had a better performance over the season with the yield of 17.86 $ton.ha^{-1}$ and similar statistic results comparing to North and South (NS) with 15.99 $ton.ha^{-1}$ and Annie Oakley (AO) with 15.24 $ton.ha^{-1}$. Cajun Delight (CD) and Millionaire (MI) had results with no statistic differences with the yield of 13.91 and 13.78 $ton.ha^{-1}$ respectively and greater yield than Clemson Spineless (CS) with 12.21 $ton.ha^{-1}$ and Santa Cruz 47 harvested based on USA market size (SC1) with 12.20 $ton.ha^{-1}$. Baby Bubba (BB) with 6.14 $ton.ha^{-1}$ had greater yield than Chifre de Veado harvested based on USA size (CV1) which had 1.82 $ton.ha^{-1}$ and showed similar results when compared to Chifre de Veado harvested based on Brazilian market size (CV2) that produced 3.53 $ton.ha^{-1}$ along the season.

In 2009, the results were similar for most of the varieties in this trial including: SC2, NS, AO, CD, CS, SC1 and BB with yield varying from 3.53 to 4.62 $ton.ha^{-1}$. The CV2 and CV1 had lower yield among the others with 2.61 and 1.98 $ton.ha^{-1}$ respectively (Figure 2.1).



ɔy Bubba (BB),
razil market
Cruz 47 (SC1
mherst, 2009

When comparing Santa Cruz 47 harvested in two different sizes, Brazilian and USA market size, SC2 produced 46.38% more than SC1 in ton per hectare and 9.00% less pods per hectare in 2010. In both pods size of Santa Cruz 47, the yield is reasonable for commercial production. The total yield in this study for 2010 was 17.86 $ton.ha^{-1}$ for SC2 and 12.20 $ton.ha^{-1}$ for SC1 higher than the results found by Duzyaman (1997) which says that yield of 12 $ton.ha^{-1}$ or above is considered an excellent yield for commercial farmers.

The yield expressed by number of pods per hectare had similar results for NS, CD, AO and MI for 2010 with production varying from 16.79 to 19.20 x 10^5 $pods.ha^{-1}$. Even though SC2 had the best yield in weight, it had fewer pods with 13.67 x 10^5 $pods.ha^{-1}$ when compared to the others varieties above. This difference might be due to the size that this plot was harvested; bigger pods could concentrate more weight with less number on total yield.

Analyzing the fruit characteristics for the experiment in 2009, statistical differences were found among the varieties of okra (Table 2.2). CV2 had the greater value for the fruit length followed by SC2 in 2009 and for 2010 both, CV2 and SC2 had the longest pods over all okra varieties. It confirms the methods chosen for this experiment when CV2 and SC2 were left on the plants until they get the size desired by the Brazilian market, which is bigger than the marketable size in the USA.

The greatest pod diameter was 17.55 and 17.11 mm for CV2 and CS, respectively, and the smallest pod diameter was 13.05 mm for SC1 in 2009. For 2010, CS had the largest pod diameter with 15.35 mm and the smallest were BB and SC1 with 12.60 and 12.25 mm diameter, respectively. There were no significant differences in diameter among CD, CV1, MI, NS and SC2 in 2010 season.

Table 2.2. Characteristics of okra fruits. South Deerfield, UMass-Amherst, 2009 and 2010.

	Weight (*g.pod*$^{-1}$)	**Length (*mm*)**	**Diameter (mm)**
		2009	
Varieties			
Annie Oakley	8.21 d	74.03 e	15.33 b
Baby Bubba	8.17 d	72.83 e	14.21 d
Cajun Delight	7.34 d	75.39 e	14.46 cd
Clemson Spineless	10.94 c	74.79 e	17.11 a
Chifre de Veado (1)	14.21 b	96.30 c	15.01 bc
Chifre de Veado (2)	28.54 a	157.79 a	17.55 a
North & South	8.50 d	76.58 e	14.69 cd
Santa Cruz 47 (1)	8.92 cd	87.15 d	13.05 e
Santa Cruz 47 (2)	15.32 b	120.34 b	15.00 bc
		2010	
Varieties			
Annie Oakley	8.37 e	77.70 de	14.30 c
Baby Bubba	7.20 f	75.32 de	12.60 e
Cajun Delight	7.52 ef	79.16 d	13.54 d
Clemson Spineless	10.16 d	74.86 e	15.35 a
Chifre de Veado (1)	11.43 c	89.37 b	13.72 d
Chifre de Veado (2)	16.65 a	119.44 a	14.79 b
Millionaire	8.21 ef	78.36 de	13.99 cd
North & South	8.30 e	79.41 d	13.81 d
Santa Cruz 47 (1)	8.12 ef	84.46 c	12.25 e
Santa Cruz 47 (2)	13.07 b	117.50 a	13.68 d

Means separation in columns and year by Duncan's new multiple range test, *P*=0.05.

CV2 had the greater pod weight in 2009 and 2010 over all okra varieties. The mean pod weight for CV2 was 28.54 grams and the other varieties varied from 7.34 to 15.32 grams in 2009 and from 7.20 to 13.07 grams in 2010.

This study was conducted in two years with significantly different weather conditions in Western Massachusetts. In 2009, the growing season was unseasonably cool, cloudy and wet, with 313 mm of rainfall and 745 accumulated growing degree days (GDD) for okra. Accumulated GDDs represent the heating units above a 10° C baseline temperature that have occurred each day from the beginning of the current calendar year. GDD are calculated by taking the average of the daily maximum and minimum temperatures compared to a baseline temperature of 10° C (Brown, 2010). It helps to explain the similar results for most of the varieties chosen and the behavior of this tropical crop in 2009. This trial in 2009 was also negatively affected by the soil-borne fungus *Verticillium spp.,* which, combined with the cold and wet weather, became very aggressive, especially in the end of the season.

In 2010, the summer was much warmer and drier than 2009, with 195 mm of rainfall and 1340 GDD during the growing season. The need for water was supplied by the irrigation system. Sunlight and high temperatures were speculated to be a major reason to the improved performance in productivity for okra comparing the results of 2010 over 2009.

Yield results suggest that most of the okra varieties can be grown in soils and climate similar to Massachusetts for commercial production. Also the Brazilian variety, Santa Cruz 47, when harvested based on the Brazilian marketable size, can have similar yield compared to Annie Oakley and North and South desired to attend the USA pod size on the markets.

2.4 References

AGRIANUAL 2010: Anuario da agricultura brasileira. Sao Paulo: FNP. 2009. p.338.

Brasileiros no Mundo-Estimativas. 2009. Ministério das Relações Exteriores – MRE, Subsecretaria Geral das Comunidades Brasileiras no Exterior – SGEB, Departamento Consular e de Brasileiros no Exterior – DCB, Divisão de Assistência Consular – DAC, Segunda Edição. Available at http://www.brasileirosnomundo.mre.gov.br/pt-br/estimativas_populacionais_das_comunidades.xml [Accessed August 2, 2011].

Brown, A. 2010. Sweet corn report. Vegetable Notes for Vegetable Farmers in Massachusetts: 21(7) 7-8.

Camciuc, M., M. Deplagne, G. Vilarem, A. Gaset. 1998. Okra - Abelmoschus esculentus L. (Moench.) a crop with economic potential for set aside acreage in France. Industrial Crops and Products 7: 257–264.

Costa, M. C. B., G.D. Oliveira, H.P. Haag. 1981. Nutrição mineral de hortaliças - Efeito da omissão dos macronutrientes e do boro no desenvolvimento e na composição química de hortaliças. Nutrição mineral em hortaliças**.** Campinas: Fundação Cargil. 6: 257-276.

Duzyaman, E. Okra: Botany and Horticulture. 1997. Horticulture Reviews 21: 41-72

FAIR-Federation for American Immigration Reform. 2011, July 23. Immigration Facts. Available in http://www.fairus.org/site/PageNavigator/facts/state_data_MA.

FAO. FAOSTAT, FAO Statistics Division 2011. Availabel at http://faostat.fao.org Accessed on July 18, 2011.

Hochmuth,G. J., D.N. Maynard, C.S. Vavrina, T.A. Stall, P.A. Kucharek, A.G. Stansly. 1999.Okra Production in Florida. Cooperative Extension Service. HS 729 FL

Izekor, S. and Katayama, R. W. 2001. Okra production update for small acreage growers. University of Arkansas at Pine Bluff, United States Department of Agriculture, and County Governments Cooperating.

Jesus, M. M. S.; M. A. G. Carnelossi; S. F. Santos; N. Narain and A. A. Castro. 2008. Inhibition of enzymatic browing in minimally processed okra. Rev. Cienc. Agron. 39 (4): 524-530.

Mota W.F., F.L. Finger, V.W.D. Casali. 2000. Olericultura: Melhoramento Genético do Quiabeiro. Viçosa: UFV. 144p.

Mota W.F., F.L. Finger, D. J. H. Silva; P. C. Correia; L. P. Firme; and L. L. M. Neves. 2005. Physical and chemical characteristics from fruits of four okra cultivars. Hortic. bras. 23 (3): 722-725.

Mendonca, R.U. 2007. Analysis of Markets in the United States for Brazilian Fresh Produce Grown in Massachusetts. Masters Theses. Paper 24. Available at: <http://scholarworks.umass.edu/theses/24>

New England Vegetable Management Guide. 2008-2009. John Howell, editor. (http://www.nevegetable.org/).

Purquerio, L. F. V., A. A. Lago, F. A. Passos. 2010. Germination and hardseedness of seeds in okra elite lines. Hortic. Bras. Brasília, 28(2).

Rao, P. U. 1985. Chemical composition and biological evaluation of okra (*Hibiscus esculentus*) seeds and their kernels. Plant Foods for Human Nutrition 35 389-396.

Simonne, E.H., W.M. Stall, S.M. Olson, S.E. Webb, and S. Zhang. 2010.Okra production in Florida. Chapter 13: 157-165.

CHAPTER 3

EVALUATION OF PLANT DENSITIES OF OKRA (ABELMOSCHUS ESCULENTUS) FOR PRODUCTION IN MASSACHUSETTS

3.1 Introduction

Also known as “quiabo” in Portuguese, okra (*Abelmoschus esculentus* (L.) Moench) is a warm-season crop that is considered to be originated from India (Rao, 1985), and it is a traditional vegetable crop commercially cultivated in West Africa, India, Southeast Asia, the southern United States, Brazil, Turkey and northern Australia (Duzyaman, 1997).

In the United States, okra is most popular in the southern part of the country, but the development of cultivars with early maturity allows cultivation in the north (Hill, 2001). Fresh okra is a popular ingredient of soups and stews where a highly viscous consistency is desired (Baxter, 1990). The nutritional value of 100 g of edible portion of okra contains 1.9 g of protein, 0.2 g fat, 6.4 g carbohydrate, 0.7 g minerals and 1.2 g fiber (Tiwari et al, 1998).

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The leading okra producing states in the United States are Texas, Florida, Georgia and California (Colditz, 2009). Mexico exports okra year round, with peak exports to the United States from June to September (Izekor and Katayama), fetched the challenge to have okra available on the shelves of markets.

Massachusetts foreign-born population has been increasing in recent years (Fair, 2008). Within their population are ethnicities that use okra in their cuisine. A Brazilian dish called “Frango com Quiabo” (chicken with okra) is especially famous in Minas Gerais, the state of origin of a very high percentage of Brazilians living in Massachusetts. According to the Brazilian Ministry of International Relations (Brasileiros no Mundo, 2009), there are about 350,000 Brazilians living in New England.

This study was implemented to determine the optimum density of okra for farmers in Massachusetts interested in producing okra for this growing demand.

3.2 Material and Methods

The experiment was conducted in the summers of 2009 and 2010 at the UMass Research Farm in South Deerfield, MA. The soil at the UMass Research Farm is an Occum fine sandy loam (coarse-loamy, mixed, mesic Fluventic Dystrudept).

In a randomized complete block design with five replications and seven different plant spacings in the row (7.5, 15.0, 22.5, 30.0, 38.5, 45.0 and 52.5 cm) were laid out in unit plots with 2.13 m by 1.83 m in double row of plants and the number of plants within each plot varied according to the density designed in between plants (Table 3.1). The

Table 3.1. Density of okra related to densities of okra plants. South Deerfield. UMass-Amherst, 2009 and 2010.

Space (cm)	Density (plants ha^{-1})
7.5	143500
15.0	71750
22.5	47850
30.0	35900
37.5	28700
45.0	23900
52.5	20500

space of 0.91 m was skipped in between plots and 1.52 m in between blocks.

Cajun Delight, the most common variety used by growers in Massachusetts due to its shorter days to harvest compared to other commercially available varieties, was chosen to be used for this trial. Seedlings were produced in round plastic flats with 72 cells (91 cm cubed/cells). Pro-Mix Bx (Premier Horticulture) was used as growing medium. Two seeds of Cajun Delight (Seed source: Johnny's Selected seeds for 2009 and Nichols Garden Nursery for 2010) were placed in each cell and thinned to one plants/cell two weeks after seeding. The flats were placed in a mist house (24 ^{o}C day and night temperatures) until germination, and then transferred to a greenhouse (21 ^{o}C day and 18 ^{o}C night temperatures) with the regime of fertilizer (Technigro 17-5-24, 200 ppm Nitrogen) applied as a constant feed. Plants were transplanted to the field 27 days after seeding in the greenhouse in 2009 and 30 days in 2010 (Table 3.2). Plants were transplanted into 8 cm raised beds, spaced 1.83m on center, covered with black plastic with drip irrigation to apply water and fertilizer when needed.

Table 3.2. Dates for selected actions for okra production. South Deerfield. UMass-Amherst, 2009 and 2010.

Action	2009	2010
Seeded in the greenhouse	May 20	May 4
Thinned in the flats	June 4	May 21
Transplanted into the field	June 16	June 3
First Harvest	July 23	July 5
Last Harvest	September 7	September 29

A single row of okra was planted on each side of the experimental area to prevent interference from the environment on plots on the two outer rows.

Water was applied via drip irrigation as needed based on soil moisture readings from tensiometers (Irrometer Co Riverside CA) placed at 15, 30, and 45 cm depths in the soil in between two plants and the drip tape, as recommended by the Irrometer Company, in one randomly selected plot.

Fertilizer was applied through the drip system in the form of a complete fertilizer (20%N - 20%P_2O_5 - 20%K_2O) and calcium nitrate (15.5%N - 0%P_2O_5 - 0%K_2O) according to soil tests taken in the early spring each year, based on the recommendations from the New England Vegetable Management Guide 2008-2009. The total amount of fertilizer applied through the drip system during both years of experiments was ($kg.ha^{-1}$): 80.27 N, 14.2 P, 14.2 K for 2009 and 105.36 N, 62.55 P, 60.10 K in 2010. Weeds in-between plastic beds and in the holes were removed by hand. Cutworms (*Agrotis sagetum*) were found in the 2009 experiment, and one application was made with Asana XL (active ingredient: esfenvalerate) at rate of 630 $g.ha^{-1}$ on June 16. Japanese beetle (*Popillia japonica*) and aphids (*Lipaphis erysimi*) were controlled in 2010 by one application of Admire 2F (1.46 $liters.ha^{-1}$; a.i. imidacloprid) applied through the drip system on June 30.

Harvest began 37 days after planting in 2009 and 32 days after planting in 2010. Okra pods appear about five days after blooming, depending on weather, and grow very quickly. Since okra pod tenderness decreases as the pod size increases, harvest was done three times a week.

The frequency of harvest, the plant spacing range, as well as other experimental characteristics were similar to the trial that S. C. Tiwari (1983) did when evaluating the effect of planting density on the yield for Clemson Spineless.

Pods were harvested, counted and fresh weight was taken. For each harvest, pods that had a minimum length of 70 mm were harvested from a selected area of 2.8 m^2 in the center of each plot. The number and fresh weight of fruits from each plot were taken. A sub-sample of five fruits per plot was randomly chosen to measure fruit weight and fruit length, using a digital caliper. Yield was expressed by number of pods and total weight.

Analyses of variance were performed by SAS and the means compared using orthogonal polynomial comparisons.

3.3 Results and Discussion

In 2009, total yield and total number of okra pods were not significantly affected by row spacing (Table 3.3). However, in 2010, the differences among the plant spacings for both pod number and weight were highly significant and represented by a quadratic relationship where the greater plant spacing for yield was '52.5 cm' with the total yield of 14.91 $ton.ha^{-1}$, and for total number of pods '37.5 cm' had the greatest results with 192.31 x 10^4 $pod.ha^{-1}$.

Table 3.3. Total yield, total number of pods and pod characteristics of okra grown at five plant spacings. South Deerfield. UMass-Amherst, 2009 and 2010.

Treatment	Yield (*ton.ha^{-1}*)	Number (*pod.ha^{-1} x 10^{4}*)	Weight (*g*)	Length (*mm*)
		2009		
Spacing (cm)				
7.5	2.25	32.59	6.93	75.88
15.0	2.45	35.70	6.99	76.93
22.5	2.53	35.19	7.17	73.72
30.0	3.13	42.96	7.25	74.78
37.5	2.69	34.30	7.71	76.63
45.0	2.87	36.81	7.82	75.83
52.5	2.73	37.85	7.11	75.10
ANOVA				
Spacing	NS	NS	NS	NS
		2010		
Spacing (cm)				
7.5	3.24	46.87	6.80	77.05
15.0	6.71	87.08	7.68	76.27
22.5	9.00	122.36	7.33	76.82
30.0	11.73	159.28	7.37	79.02
37.5	14.09	192.31	7.34	78.44
45.0	14.28	185.64	7.66	78.99
52.5	14.41	181.85	7.83	78.25
ANOVA				
Spacing ^{Y}	**Q	**Q	NS	NS

ns,*,** Non-significant or significant at P= 0.05 or 0.01, respectively.

^{Z} Q represents a significant quadratic relation between density and the measured parameter.

This study was conducted in two years with significantly different weather conditions in Western Massachusetts. In 2009, the period during the cultivation of okra was unseasonably cool, cloudy and wet, with 313 mm of rainfall and 745 accumulated growing degree days (GDD) during the growing season of okra. Accumulated GDDs represent the heating units above a 10° C baseline temperature that have occurred each day from the beginning of the current calendar year. GDD are calculated by taking the average of the daily maximum and minimum temperatures compared to a baseline temperature of 10° C (Brown, 2010). It helps to explain the similar results for all the spacing chosen and the behavior of this tropical crop in 2009. This trial in 2009 was also negatively affected by the soil-borne fungus *Verticillium spp.,* which combined with the cold and wet weather became very aggressive especially in the end of the season.

In 2010, the summer was much warmer and drier than 2009, with 195 mm of rainfall and 1340 GDD during the growing season. The need for water was supplied by the irrigation system. Sunlight and high temperatures were speculated to be a major reason to the improved performance in productivity for okra comparing the results of 2010 over 2009.

There were no statistical differences among treatments for average pod size and weight in 2009 or 2010 (Table 3.3). As the pod size was standardized to be harvested when they reached the marketable size on length and the average of pod weight varied from 6.80 to 7.83 $g.pod^{-1}$.

Decreasing the plant population by increasing the spacing between plants significantly increase the yield and also the number of pods of okra. The interpretation of the results for 2010, shows that the lowest yield and the lowest number of pods of okra were obtained from the closest spacing (7.5 cm) with 3.24 $ton.ha^{-1}$ and 46.87×10^4 $pod.ha^{-1}$ respectively. This might be due the competition for nutrients and sunlight and space among the roots and plants owing to maximum plant population. However, the spacing of ‘37.5 cm’ obtained the highest number of okra pods with 192.31×10^4 pods and the spacing of '52.5'cm (20500 plants.ha^{-1}) had the greatest yield with 14.91 ton.ha^{-1} for the season. A study conducted by Simonne in 2002, found a yield of 14.98 ton.ha^{-1} of okra when evaluating Cajun Delight with 21535 plants per hectare grown with plasticulture with drip irrigation in Suwannee, Florida.

High plant densities have more growing points early of the season, but increased branching of plants at the lower density increasing the growing points, may have caused the higher yields for the lower densities compared to the densities where the plants had bigger spacing in between them.

The yield of okra was significant affected by date. The yield for 2009 and 2010 increased from the first harvest until the harvest on the weeks of August 16 and 23 when the highest yield occurred for both years. Then the yield dropped until the last date of harvest for 2009 and 2010 (Figure 3.1).

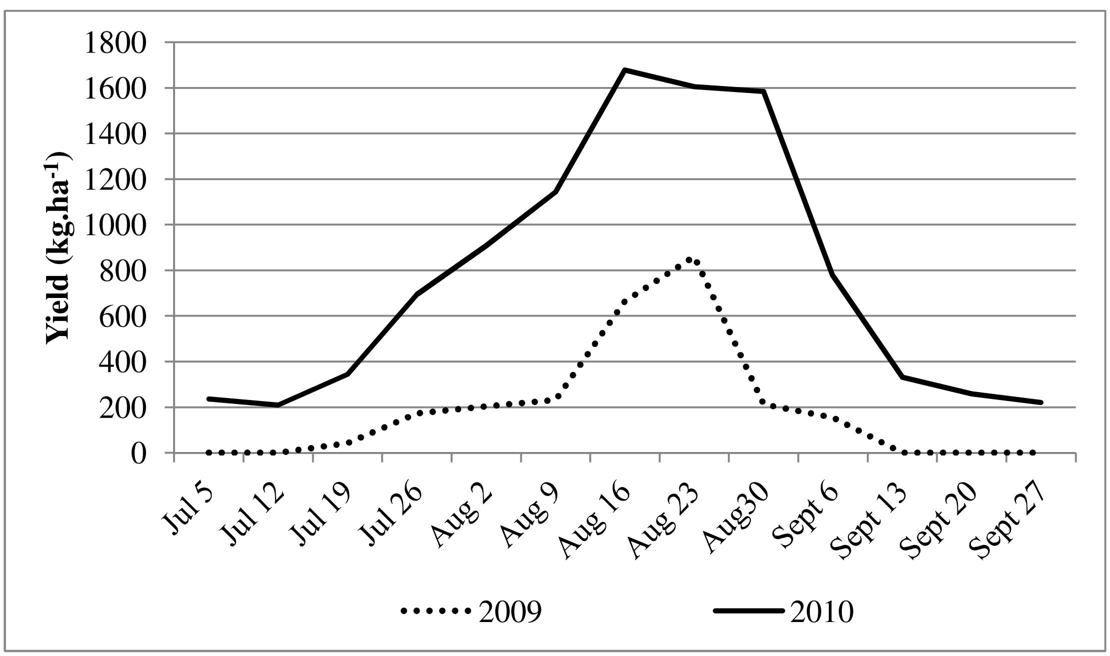

Figure 3.1. Yield of okra. South Deerfield. UMass-Amherst, 2009 and 2010.

3.4 References

Albregts, E.E., C. M. Howard. 1974. Response of okra to plant density and fertilization. HortScience. 9:400.

Amjad, M., M. A Anjum and A. Ahmed. 2001. Effect of phosphorus and planting density on seed production in okra. Int. J. Agri. Biol., Vol. 3, No. 4.

Baxter, L., L. Waters Jr. 1990. Controlled atmosphere effects on physical changes and ethylene evolution in harvested okra. HortScience 25(1): 92-95.

Brasileiros no Mundo-Estimativas. 2009. Ministério das Relações Exteriores – MRE, Subsecretaria Geral das Comunidades Brasileiras no Exterior – SGEB, Departamento Consular e de Brasileiros no Exterior – DCB, Divisão de Assistência Consular – DAC, Segunda Edição. Available at http://www.brasileirosnomundo.mre.gov.br/pt-br/estimativas_populacionais_das_comunidades.xml [Accessed August 2, 2011].

Brown, A. 2010. Sweet corn report. Vegetable Notes for Vegetable Farmers in Massachusetts: 21(7) 7-8.

Colditz, P., D. Granberry, C. Vavrina. 2009. Okra Commercial Vegetable Production.Learning for life. Circular 627.

Duzyaman, E. Okra: Botany and Horticulture. 1997. Horticulture Reviews 21: 41-72

Hill, D. E. 2001. Specialty crops: okra, leek, sweet potato, and jilo. Connecticut Agriculture Experiment Station. Bulletin 976: 1-13

Izekor, S. and Katayama, R. W. Okra production update for small acreage growers. University of Arkansas at Pine Bluff, United States Department of Agriculture, and County Governments Cooperating.

Lazarovits, G., K.L. Conn, and M. Tenuta. 2000. Control of *Verticillium dahliae* with soil amendments: efficacy and mode of action. Advances in Verticillium: Research and Disease Management. 274–291.

Locke, T. and S. Buck. 2000. The effect of linseed cropping on *Verticillium dahlia* soil infestation levels. Advances in Verticillium: Research and Disease Management. 343–346.

New England Vegetable Management Guide. 2010-2011. John Howell, editor. (http://www.nevegetable.org/).

Olczyk, T., K. Cushman, W. Klassen. 2005. Plant population affects growth and yield of okra(Abelmoschus esculentus) in South Florida, USA. Proc. Interamer. Soc. Trop. Hort. 48: 54-56.

Rao, P. U. 1985. Chemical composition and biological evaluation of okra (*Hibiscus esculentus*) seeds and their kernels. Plant Foods for Human Nutrition 35 389-396.

SAS Institute, Inc. (2008). Base SAS 9.2. Cary, NC: SAS Publishing.

Simonne, E.; B. Hochmuth; J. Simons; E. Vinson; and A. Caylor. 2002. Evaluation of new okra cultivars for bare ground and plasticulture production. HortTechnology 12(3): 470-476.

Strobel, J.W. 1961. Verticillium wilt of okra and southern pea in Southern Florida. Florida State Horticultural Society. Florida Agricultural Experiment Stations Journal Series. No 1326: 171-175.

Strunnikova, O.K., N.A. Vishnevskaya and G.S. Muromtsev. 2000. Abundance of mycelium and microsclerotia as indices of the soil status of *Verticillium dahlia.* Advances in Verticillium: Research and Disease Management. 125–128.

Tiwari, K.N.,P.K. Mal,R.M. Singh, A.Chattopadhyay. 1998. Response of okra (Abelmoschus esculentus (L.) Moench.) to drip irrigation under mulch and non-mulch conditions. Agricultural Water Management 38: 91-102.

Tiwari, S.C., Igbokwe P. E., Collins J. B.. 1983. Effect of Planting Density on the Yield of 'Clemson Spineless' Okra (Abelmoschus esculentus (C.) Moench). Reaserch Report MAFES. Vol. 8, No. 7.

Weiner, J. 1990. Plant population ecology in agriculture. In: C.R. Carrol, J.H. Vandermeer and P.M. Rosett (Eds.). *Agroecology.* McGraw Hill Book Company Inc., New York.

Whitehead, W.F., B.P. Singh. 2000. Yield, time of maximum CO2 exchange rate, and leaf-area index of Clemson Spineless okra are affected by within-row spacing. HortScience 35: 849-852.

WORLD CROP for the Northeastern United States. Okra Abelmoschus esculentus. Available in http://www.worldcrops.org/crops/Okra.cfm. Accessed in August, 2010.

CHAPTER 4

CONCLUSIONS

Historically, okra has been, most popular in the southern part of the United States, but with the development of early-maturing cultivars and the growing number of immigrant populations in the northern parts of the country that use okra in their cuisine open new opportunities for farmers to grow okra in New England. This large foreign-born population has a strong preference for their traditional cuisine and with the volume of okra imported every year, local production of okra represents a demand of fresh okra in the market.

Okra is very popular in Brazil, where it is used in many dishes; in the state if Minas Gerais it is used most frequently in dish called “Frango com Quiabo” (chicken with okra). Santa Cruz 47 is the most commonly grown variety of okra in Brazil. When harvested based on the size desired by the Brazilian market, Santa Cruz 47 had the best performance in total yield with less number of pods harvested. However, it is critical that growers have a thorough understanding of the size of okra desired by the Brazilian market.

Yield results from these trial show that the varieties: North and South, Annie Oakley, Cajun Delight, Millionaire, Clemson Spineless, Santa Cruz 47 harvested based on Brazilian market size and Santa Cruz 47 harvested based on United States market size, can be commercially grown in Massachusetts with climate similar to 2010 season and in absence of severe Verticillium pressure. When left to grow to the size desired by the

Brazilian market, the fruits of Santa Cruz 47 had higher yields than the fruits harvested based on the United States market size.

The results of this study show that with a season similar in temperature and rain fall to 2010, the recommended plant spacing of okra is 52.5 cm in double row for highest yield. Increasing the plant population by decreasing the spacing in between plants tends to decrease total yield and also the number of immature okra pods.

It is importance of farmers to know the costs and returns of the crops they grow is very relevant in order for them to fully evaluate the viability for specific crops and estimate potential profits. An enterprise budget was created for okra grown at the UMass Research Farm in South Deerfield-MA in 2010 (Table 4.1). The costs and returns were based on the variety Cajun Delight with the plant population of 20500 plants per hectare grown on raised beds with black plastic and drip irrigation.

Changes of the climate among the years affect significantly the performance of okra due to the temperature and the availability of sun light. Okra also becomes more susceptible to diseases that can become more virulent when the climatic conditions are not as favorable for okra and more favorable for diseases.

Farmers are always interested in new markets and it can be a challenge to introduce a new crop to their rotation. In the view of this study, it has become necessary to develop a strategic method to market okra and help the farmers to understand the supply chain for okra in Massachusetts and the Northeastern US. Therefore, promotional materials, such as nutritionally-balanced recipes, point-of-sales materials, need to be part of a marketing component in order to provide useful information for costumers.

Table 4.1. Enterprise budget for variable costs for the okra variety Cajun Delight. South Deerfield. UMass-Amherst, 2010.

Labor costs[Y] (based on 1 hectare) - 2010		
	Labor hrs ($12.00 hr^{-1})	Machinery hrs ($20.00 hr^{-1})
Disk harrow	1	1
Lay plastic and drip tape	10	10
Set up trickle system	10	-
Set transplants	28	-
Irrigate and apply fertilizer through drip	55	-
Cultivate in between plastic (5 times)	130	-
Harvest and pack	483	-
Remove black plastic	28	14
Seed cover crops	1	1
Total hours	**746**	**26**
Total labor and machinery costs	**$8,952.00**	**$520.00**
Material (based on 1 hectare)		
Soils test		$40.00
Seed[1]		$1,350.00
Transplants[2]		$2,707.00
Fertilizer through drip[3]		$1,353.69
Black plastic mulch and drip tape[4]		$918.72
Boxes[5]		$1,487.00
Total material costs		**$7,856.41**
Total costs and returns (based on 1 hectare)		
Labor costs		$8,952.00
Machinery cost		$520.00
Material costs		$7,856.41
Total costs		**$17,328.41**
Total returns[6]		**$22,305.00**
Net (total returns – total costs)		**$4,976.59**

[Y] Labor costs based on two people working on research experiments in 2010
[1] Based on U$ 900.00 per kg; 15000 seeds per kg
[2] Based on 285 flats of 72's; $9.50 per flat at Harvest Farm of Whately, MA
[3] 13 bags of calcium nitrate (22.7 kg) at $12.63 bag; 26 bags of 20-20-20 (11.3Kg) at $ 45.75 bag
[4] Plastic and drip tape laid 1.82 meters on center – 5468 m.ha^{-1}
[5] Based on 1487 boxes, $1.00 box
[6] 1487 boxes @ $15.00 box

BIBLIOGRAPHY

AGRIANUAL 2010: Anuario da agricultura brasileira. Sao Paulo: FNP. 2009. p.338.

Albregts, E.E., C. M. Howard. 1974. Response of okra to plant density and fertilization. HortScience. 9:400.

Amjad, M., M. A Anjum and A. Ahmed. 2001. Effect of phosphorus and planting density on seed production in okra. Int. J. Agri. Biol., Vol. 3, No. 4.

Baxter, L., L. Waters Jr. 1990. Controlled atmosphere effects on physical changes and ethylene evolution in harvested okra. HortScience 25(1): 92-95.

Brasileiros no Mundo-Estimativas. 2009. Ministério das Relações Exteriores – MRE, Subsecretaria Geral das Comunidades Brasileiras no Exterior – SGEB, Departamento Consular e de Brasileiros no Exterior – DCB, Divisão de Assistência Consular – DAC, Segunda Edição. Available at http://www.brasileirosnomundo.mre.gov.br/pt-br/estimativas_populacionais_das_comunidades.xml [Accessed August 2, 2011]. Brown, A. 2010. Sweet corn report. Vegetable Notes for Vegetable Farmers in Massachusetts: 21(7) 7-8.

Brown, A. 2010. Sweet corn report. Vegetable Notes for Vegetable Farmers in Massachusetts: 21(7) 7-8.

Camciuc, M., M. Deplagne, G. Vilarem, A. Gaset. 1998. Okra - Abelmoschus esculentus L. (Moench.) a crop with economic potential for set aside acreage in France. Industrial Crops and Products 7: 257–264.

Colditz, P., D. Granberry, C. Vavrina. 2009. Okra Commercial Vegetable Production.Learning for life. Circular 627.

Costa, M. C. B., G.D. Oliveira, H.P. Haag. 1981. Nutrição mineral de hortaliças - Efeito da omissão dos macronutrientes e do boro no desenvolvimento e na composição química de hortaliças. Nutrição mineral em hortaliças**.** Campinas: Fundação Cargil. 6: 257-276.

Duzyaman, E. Okra: Botany and Horticulture. 1997. Horticulture Reviews 21: 41-72.

FAIR-Federation for American Immigration Reform. 2011, July 23. Immigration Facts. Available in http://www.fairus.org/site/PageNavigator/facts/state_data_MA.

FAO. FAOSTAT, FAO Statistics Division 2011. Availabel at http://faostat.fao.org Accessed on July 18, 2011.

Hill, D. E. 2001. Specialty crops: okra, leek, sweet potato, and jilo. Connecticut Agriculture Experiment Station. Bulletin 976: 1-13.

Hochmuth,G. J., D.N. Maynard, C.S. Vavrina, T.A. Stall, P.A. Kucharek, A.G. Stansly. 1999.Okra Production in Florida. Cooperative Extension Service. HS 729 FL

Izekor, S. and Katayama, R. W. 2001. Okra production update for small acreage growers. University of Arkansas at Pine Bluff, United States Department of Agriculture, and County Governments Cooperating.

Jesus, M. M. S.; M. A. G. Carnelossi; S. F. Santos; N. Narain and A. A. Castro. 2008. Inhibition of enzymatic browing in minimally processed okra. Rev. Cienc. Agron. 39 (4): 524-530.

Lazarovits, G., K.L. Conn, and M. Tenuta. 2000. Control of *Verticillium dahliae* with soil amendments: efficacy and mode of action. Advances in Verticillium: Research and Disease Management. 274–291.

Locke, T. and S. Buck. 2000. The effect of linseed cropping on *Verticillium dahlia* soil infestation levels. Advances in Verticillium: Research and Disease Management. 343–346.

Mota W.F., F.L. Finger, V.W.D. Casali. 2000. Olericultura: Melhoramento Genético do Quiabeiro. Viçosa: UFV. 144p.

Mota W.F., F.L. Finger, D. J. H. Silva; P. C. Correia; L. P. Firme; and L. L. M. Neves. 2005. Physical and chemical characteristics from fruits of four okra cultivars. Hortic. bras. 23 (3): 722-725.

Mendonca, R.U. 2007. Analysis of Markets in the United States for Brazilian Fresh Produce Grown in Massachusetts. Masters Theses. Paper 24. Available at: <http://scholarworks.umass.edu/theses/24>

New England Vegetable Management Guide. 2008-2009. John Howell, editor. (http://www.nevegetable.org/).

Olczyk, T., K. Cushman, W. Klassen. 2005. Plant population affects growth and yield of okra(Abelmoschus esculentus) in South Florida, USA. Proc. Interamer. Soc. Trop. Hort. 48: 54-56.

Purquerio, L. F. V., A. A. Lago, F. A. Passos. 2010. Germination and hardseedness of seeds in okra elite lines. Hortic. Bras. Brasília, 28(2).

Rao, P. U. 1985. Chemical composition and biological evaluation of okra (*Hibiscus esculentus*) seeds and their kernels. Plant Foods for Human Nutrition 35 389-396.

SAS Institute, Inc. (2008). Base SAS 9.2. Cary, NC: SAS Publishing.

Simonne, E.; B. Hochmuth; J. Simons; E. Vinson; and A. Caylor. 2002. Evaluation of new okra cultivars for bare ground and plasticulture production. HortTechnology 12(3): 470-476.

Simonne, E.H., W.M. Stall, S.M. Olson, S.E. Webb, and S. Zhang. 2010.Okra production in Florida. Chapter 13: 157-165.

Strobel, J.W. 1961. Verticillium wilt of okra and southern pea in Southern Florida. Florida State Horticultural Society. Florida Agricultural Experiment Stations Journal Series. No 1326: 171-175.

Strunnikova, O.K., N.A. Vishnevskaya and G.S. Muromtsev. 2000. Abundance of mycelium and microsclerotia as indices of the soil status of *Verticillium dahlia.* Advances in Verticillium: Research and Disease Management. 125–128.

Tiwari, K.N.,P.K. Mal,R.M. Singh, A.Chattopadhyay. 1998. Response of okra (Abelmoschus esculentus (L.) Moench.) to drip irrigation under mulch and non-mulch conditions. Agricultural Water Management 38: 91-102.

Tiwari, S.C., Igbokwe P. E., Collins J. B.. 1983. Effect of Planting Density on the Yield of 'Clemson Spineless' Okra (Abelmoschus esculentus (C.) Moench). Reaserch Report MAFES. Vol. 8, No. 7.

Weiner, J. 1990. Plant population ecology in agriculture. In: C.R. Carrol, J.H. Vandermeer and P.M. Rosett (Eds.). *Agroecology.* McGraw Hill Book Company Inc., New York.

Whitehead, W.F., B.P. Singh. 2000. Yield, time of maximum CO2 exchange rate, and leaf-area index of Clemson Spineless okra are affected by within-row spacing. HortScience 35: 849-852.

WORLD CROP for the Northeastern United States. Okra Abelmoschus esculentus. Available in http://www.worldcrops.org/crops/Okra.cfm. Accessed in August, 2010.